

AN UNMANNED UNTETHERED INSPECTION VEHICLE

D. Richard Blidberg
University of New Hampshire
Marine Systems Engineering Laboratory
Durham, NH 03824

Arthur S. Westneat
University of New Hampshire
Marine Systems Engineering Laboratory
Durham, NH 03824

Abstract

Technology development, centered about the microprocessor as applied to an autonomous underwater vehicle, called EAVE, is described. Ongoing programs in navigation, communication, and computer development, in support of EAVE, are reviewed.

1. Introduction

The advent of the microprocessor has stimulated substantial progress both in making measurements in the ocean, and in performing routine underwater tasks. The water body lying between the human and the work station is generally opaque and dangerous, and is a difficult barrier. In concept, the solid state revolution permits the placement of systems, at the work station, that may analyze, control, and respond. The operator may be relieved of much of the routine of his control or observation task, and the usually constricted data channel imposed between himself and the work station may be employed to transmit information and not data, if the remote point is intelligent.

The Marine Systems Engineering Laboratory of the University of New Hampshire has been engaged in applying microprocessor systems to a variety of remote underwater measurement tasks. Under the sponsorship of the U.S. Geological Survey, and the Naval Ocean Systems Center, the Laboratory has constructed an experimental vehicle, called EAVE, Experimental Autonomous Vehicle, designed to serve as a test bed for the development of new technology in underwater inspection of offshore pipelines and structures, where use of divers and tethered unmanned submersibles are inappropriate.

An extended range of related technologies are being explored that will provide improved understanding of intelligent underwater systems, and that could lead to fully autonomous operation of small unmanned submersibles. Among the several areas of study are:

- Adaptation of a UNH-built submersible platform to serve as a test bed for the evolving systems under evaluation. A key feature of this platform is its

response to commands with five degrees of freedom.

- Development of a reliable, very low power, and yet sophisticated computer capable of the full range of computational power that may ultimately be needed to perform a fully autonomous operation.
- Development of a sonar sensor system, a ring of a dozen transducers, providing information to the computer which permits it to direct the vehicle to acquire, and then to track an exposed pipeline.
- Development of a short range navigation system which ties the vehicle into a geodetic grid. This system employs a separate microprocessor that serves as one part of a distributed computational system on the vehicle.
- Development of a communication link which permits the vehicle to report status, and the operator to intervene or to change the vehicle's status or programming.
- Establishment of a test range in Lake Winnepesaukee, NH, which is equipped to evaluate the vehicle's performance.

2. The EAVE Platform

The EAVE platform consists of a structure that supports three pairs of thrusters, each pair capable of forward and backward rotation, which permits motion in the three orthogonal axes, and through differential powering, rotation about two of the axes. The structure also supports a battery housing, and pressurized containers for the computer and associated electronics, and for navigation and communication systems. Figure 1 shows a view of the vehicle. The performance of the platform is summarized in Table 1. Although the platform could eventually take many forms, in the EAVE program the platform is not an end in itself, but a means of developing further understanding of autonomous vehicle working systems.

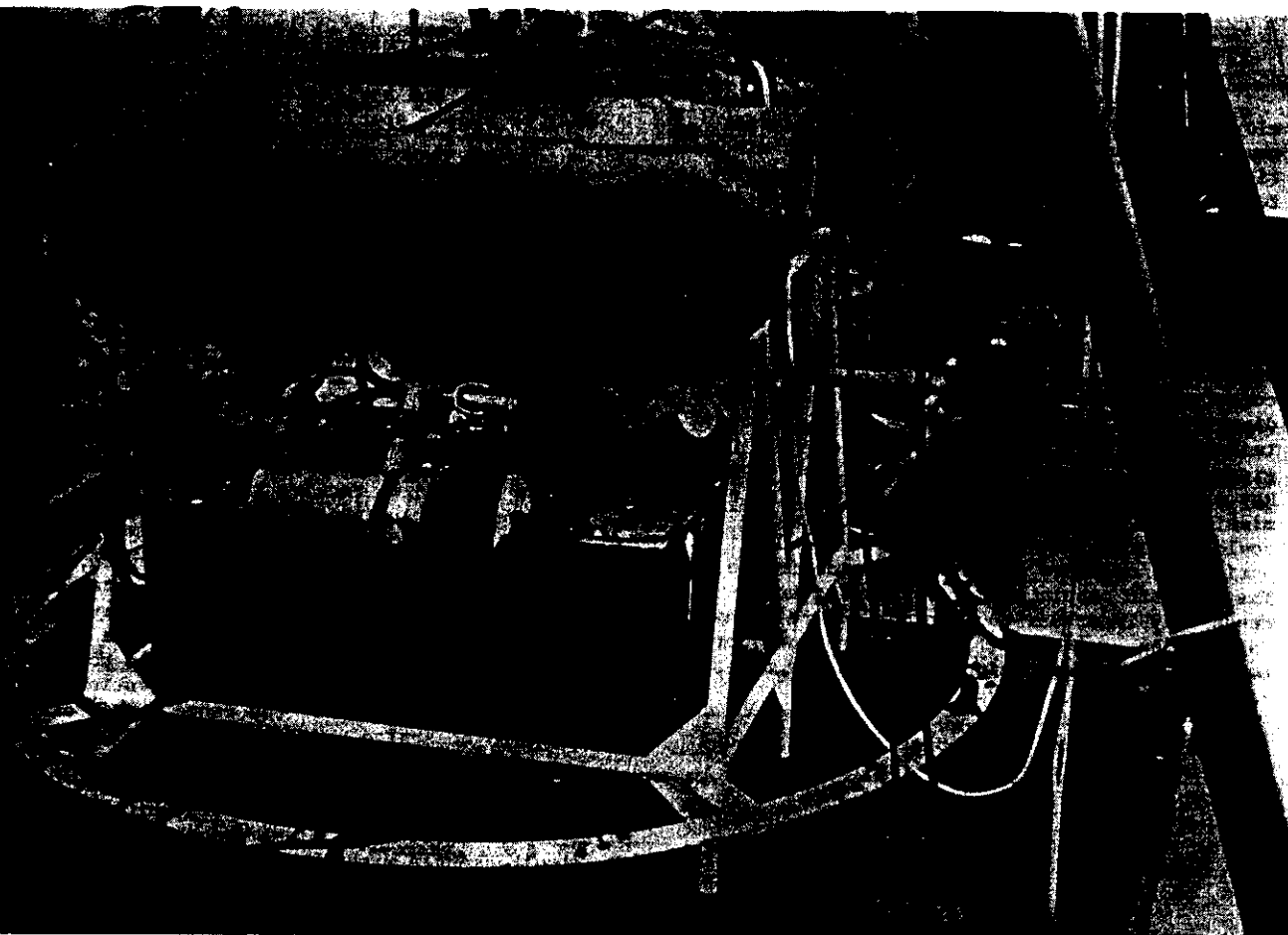


Figure 1. UNH Submersible

TABLE 1 - PRINCIPAL CHARACTERISTICS

OVERALL DIMENSIONS

LENGTH X BREADTH X HEIGHT	5'-0" x 5'-0" x 3'-8"
DISPLACEMENT SUBMERGED	691.5 LBS.
WEIGHT	687.4 LBS.
POSITIVE BUOYANCY	4.1 LBS.
PAYLOAD	SEE NOTE
STATICAL STABILITY (BG)	0.40 FT. (POS)
SPEED (MAX - NO CURRENT)	2.0 KNOTS
POWER (AT MAX SPEED)	0.50 H.P.
MANEUVERING (THRUST/MOMENT)	
X - AXIS (SURGE)	34.0 LBS.
Y - AXIS (SIDDLE/PITCH)	34.0 LBS./136.0 FT. LBS.
Z - AXIS (DEPTH CONTROL/YAW)	34.0 LBS./85.0 FT. LBS.

NOTE: PAYLOAD = "MISSION EQUIPMENT" FOR PIPELINE SURVEY
& MONITORING. SPACE FRAME CAN EASILY CARRY
BUOYANCY PACKAGES SUPPORTING 100 LBS. PAYLOAD
WHEN ON BOARD.

3. The Computer

In a time when the computational powers of microprocessors are proliferating, and large numbers of competing devices vie for our attention, it is important to note that the competence of the CPU (Central Processing Unit) is scarcely a limiting problem. In the ocean, where events occur slowly, and processes are of long duration, almost any of the available chips may serve our needs. When the systematic processes being handled by the computer begin to stress a single chip's capability, we repeatedly find ourselves relying on the concept of multiple computers, where tasks are delegated to subordinate microprocessors to accomplish the needed tasks. Reliability of the system, ease of programming, and low power supply drain have been key objectives in our design process. For some missions, a large non-volatile memory which could be completely shut down for extended periods to conserve power would be desirable. The magnetic bubble memory is playing an increasingly important role in our future plans. Through the courtesy of Texas Instruments, prototype memories are being evaluated for the vehicle system computer.

The present EAVE computer is built around the 6100 microprocessor chip, chosen because its instruction set parallels the ubiquitous PDP-8 and because it is CMOS, drawing minimal power. Furthermore, the system may be shut down during inactive periods, to resume operation, on command, without loss of function.

4. The Sensor System

The EAVE system is designed to be a test bed for technology relating to autonomous vehicle operation, and thus the sensors which it may carry are a supporting function, rather than the focus of our development effort. In the present EAVE configuration, the principal sensor that is installed is a ring of 12 sonar pingers mounted underneath the vehicle. A dozen echo path lengths may be computed, and a decision made by the computer as to whether an exposed pipeline, or other similar target, has shortened one or more of the paths. Logic in the computer memory then institutes either a search or a track routine. If indeed the vehicle is over the pipe, it is then capable of following the pipe. Presumably, in an inspection scenario the vehicle would carry still other sensors to make judgements on electrolysis, or product leakage from the pipeline or whatever other mission were assigned. The sonar ring is an excellent initial sensor for development of the vehicle, for it presents a range of control, analysis, and detection problems to the computer.

5. The Navigation Systems

The scope of the vehicle navigation system

must obviously relate to the mission that it must serve. No one system can serve these several requirements, and navigation, like the sensor suite, must be chosen specifically for the task assigned.

In the development of the EAVE, it was essential to use a system that permitted the vehicle to approximate the conditions of autonomy. Two systems have evolved that are being installed at Lake Winnepesaukee to support the vehicle development. They differ widely in concept.

6. The Vehicle Tracking System

The vehicle carries an acoustic beacon that is pulsed by a precision on-board clock. Three receiving hydrophones, placed appropriately around the range, receive the vehicle's transmissions. The range to the vehicle is computed, since the time of transmission is accurately known. This essential data is converted, in a separate microprocessor system, to cartesian coordinates and the vehicle's position may be printed out as a time series. The data also goes to a video terminal where the vehicle position is noted by a cursor in a field representing the geodetic coordinates of the range. This display may also be scaled and relative positions observed down to the intrinsic accuracy of the system, which is estimated to be in the order of inches. The location of the test pipeline may also be stored in terminal memory, and displayed simultaneously with the cursor. With this system, the relative distances between the transponder on the vehicle and any position on the range may be measured. Response of the vehicle to commands stored in the memory or imposed via the acoustic link may be observed. The systematic errors resulting from acoustic noise, from changing servo system characteristics, and various forms of error-correcting coding, from multipath, and from the other variables that affect vehicle performance may be studied.

Obviously, the system may be reversed in concept. The receiver may be placed on the vehicle, and the set of stationary bottom-located transducers may be driven by a common pulse. The software for position determination then becomes resident in the vehicle computer memory. This vehicle-centered system is envisioned as an essential navigational system for ultimate use in structural inspections. At that time, the system will be expanded to three dimensions.

7. The Range-Angle System

It is apparent that, on occasion, the vehicle must transit, and will not be within a field of carefully located transducers comprising the precision navigation field. A separate navigation system will be tested that measures range and bearing to a single beacon at a known point. Here a closely spaced group of hydrophones on the vehicle all receive a wave train from an acoustic beacon. The phase differences

between the three arrivals is processed by an on-board microprocessor, and the angle of arrival of the signal, with reference to a compass heading, is computed. A precision on-board clock permits a computation of range to the beacon. This system is less accurate than the previous system, but places far less demand on support facilities. The accuracy, moreover, increases as range shortens, giving it excellent promise as a homing system.

It is apparent that any navigation system in the ocean has at best a limited range of applicability, and is best suited for specific missions. The several systems under study on the EAVE program are tools to evaluate vehicle performance, serving to develop an understanding of the vehicle's requirements for future missions.

In Figure 2, the potential navigation system requirements are outlined, listing seven of the systems needed to serve possible vehicle missions.

8. The Communication System

To be autonomous and yet to still be a responsive tool, the vehicle must be able to communicate. As in the case of navigation, the actual specifications of the system will be a function of the mission imposed on the vehicle.

Figure 3 reviews the wide ranging, and conflicting, needs for vehicle communication as a function of the mission.

For the EAVE development, exploratory and short range, a simple 2-way pulsed data communication link was chosen.

It has been observed that a work vehicle may have to serve in roles where the communication path is extended and the noise levels are high. As a consequence, in the EAVE development, attention has been placed on computer-based means of reducing message error. It has been noted that the messages the vehicle is called upon to process differ in their priority and in the importance of any transmission errors. Three levels of priority, as well as impact of potential errors, were established. They are:

- a) Command and control messages. These are deemed to be of highest priority. They are repeated back to the sender to be verified against a copy of the transmitted message.
- b) Operational messages. These relate to supervisory control or possibly summary status messages. Here a Hamming Code for error detection and correction is transmitted. This fundamentally serves to add redundancy to the transmitted signal to insure a high level of message integrity.

- c) Data messages. Much of the data generated may prove to be largely statistical in nature, where errors in transmission entail little cost. Here the system will employ only simple parity checking to indicate potential areas of error.

9. The Test Range

The University has been fortunate to have use of a portion of Lake Winnepesaukee, off Diamond Island, as a test facility. The bed of the lake supports a simulated pipeline 300 feet in extent, in water of about 40 feet depth, as shown in Figure 4. The range is equipped with the tracking system, that provides a monitor display of the vehicle's position on the range, and the data communication system for exchanging data with the vehicle.

10. Software

It is perhaps symptomatic of the state of today's technology, that this ocean-engineering program, centered around novel hardware, is in truth extraordinarily software dependant. The problems encountered in the program and indeed what creativity may exist in it are largely expressed in the software instructions that guide the computer. The evolution of attention from device to concept found in the EAVE program, typifies the trend for future ocean-technologists.

References

1. Blidberg, D. R., Allmendinger, E., and Sideris, N., "The development of an unmanned, self-controlled, free-swimming vehicle," Offshore Technology Conference, 1978.
2. Marine Systems Engineering Laboratory, "The engineering design and development of a microcomputer controlled unmanned free-swimming vehicle," Final Report, 1978.

FIGURE 2

AUTONOMOUS VEHICLE NAVIGATION NEEDS
AS A FUNCTION OF IT'S INSPECTION NEEDS

<u>MISSION</u>	<u>RANGE</u>	<u>ACCURACY</u>	<u>POSSIBLE SYSTEM</u>
AREA MAPPING	10-100KM	300M	BEACON FIXES HYBRID SYSTEM
PIPELINE INSPECTION			
ACQUISITION	5KM	10M	BEACON FIXES
TRACKING	100M	1/2M	MAGNETIC/ACOUSTIC
SUB-SEA STRUCTURE INSPECTION			
ACQUISITION	5KM	10M	BEACON FIXES
POSITIONING	100M	1/2M	ACOUSTIC/VISUAL
OFFSHORE STRUCTURE INSP.	100M	1/2M	3 DIMENSIONAL SYSTEM BEACON ARRAYS, AND/OR COMPUTER MEMORY MAPS
VEHICLE RECOVERY	500M	2M	HOMING SYSTEM

FIGURE 3

AUTONOMOUS VEHICLE COMMUNICATION NEEDS
AS A FUNCTION OF IT'S INSPECTION MISSION

<u>MISSION</u>	<u>RANGE</u>	<u>TYPE OF DATA</u>	<u>IMPORTANCE OF ERRORS</u>	<u>DATA RATE</u>
AREA MAPPING	10-100KM	COMMAND AND CONTROL STATUS REPORT MAP DATA	HIGH MEDIUM LOW	LOW LOW HIGH-BURST
PIPELINE INSPECTION	5KM	COMMAND AND CONTROL STATUS REPORT	HIGH HIGH	LOW LOW
SUB-SEA STRUCTURE INSPECTION	1KM	COMMAND AND CONTROL STATUS REPORT IMAGE	HIGH HIGH LOW	LOW LOW HIGH-BURST
MAJOR STRUCTURE INSPECTION	100KM	COMMAND AND CONTROL STATUS REPORT IMAGE	HIGH HIGH LOW	LOW LOW HIGH-REAL TIME

FIGURE 4

